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Short-Term Variable—Head Hydrothermal Generation Scheduling for Heuristic Search Method

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***Abstract*—This paper based on Heuristic method to solve the short-term variable head hydrothermal generation scheduling problem. It uses Heuristic search method to find the result of all thermal and hydro power plants optimization. Numerical experiment show, this method to solve the non-linear problem with its available of constraints in acceptable time.**

***Index Terms*—Variable Head Hydro-thermal generation system, Heuristic search method and maximum iterations.**

1. Introduction

The optimum hydro and thermal generation scheduling of an electric power system is the find of the generation for every generating station such that the total system optimum generation cost is minimum while satisfying the constrains. However due to insignificant operating cost of hydro plants the scheduling problem essentially reduces to minimizing the fuel cost of thermal plants constrained by the generation limits, available water, and the energy balance condition for the given period of time.

This paper is based on hybrid based on a Heuristic search method which finds the optimization schedules of all hydroelectric and thermal power plants optimization without decomposition. The computational results with hydrothermal test system demonstrate that programming is an efficient and advantageous optimum method to solve the short-term planning task.

2. Heuristic Search Method

This method is not found the best solution but guaranteed the find good solution in reasonable time, and increases the efficiency, useful in solve the problems which, Could not be solved any other way, and Solutions take an infinite time or very long time to compute.

3. Problem Formulation

This problem formulates and solve in mathematically

$F_i(P_{ik})$ The cost of a fuel function of thermal power generating in the Interval k.

S_j — Reservoir surface area of j^{th} reservoir.

t_k — Duration of the k^{th} sub –interval.

P_{Dk} — Load demand during the k^{th} sub-interval.

V_j —Available water for whole period for j^{th} hydro unit.

P_{ik} —Power plant of i^{th} thermal generation in k^{th} interval.

P_i^{max} —Maximum energy of i^{th} generating thermal and hydro unit in MW.

P_i^{min} —Maximum energy of i^{th} generating thermal and hydro unit in MW.

a_i, b_i, c — Coefficients of cost the i^{th} thermal units.

x_j, y_j, z_j — Coefficients of Discharge the j^{th} hydro plant.

$\alpha_j, \beta_j, \gamma_j$ – Discharge coefficients of head of the j^{th} hydro plant.

F_i – Thermal cost of the i^{th} unit.

q_{jk}-the discharge rate from the j^{th} hydro in the k^{th} interval.
h_{jk}-Head of j^{th} hydro unit during k^{th} sub interval.
I_{jk} -Inflow in j^{th} hydro plant in k^{th} interval.
P_{Lk}-Transmission losses during the k^{th} interval.
r_k - Penalty parameter.
j- Index for hydro units.
i-Index for thermal units.
k- Index of time period.
B- Coefficients of transmission losses.
Y- Mutation factor.
M- Number of hydro plants.
T- All period for generation scheduling.
N- Number of thermal units

$$Minimize\ J \sum_{k=1}^{T} \sum_{i=1}^{N} t_k\, F(P_{ik}) \ \ldots\ldots\ldots.\ (1)$$

1. Energy continuity equation
$\sum_{i=1}^{N+M} P_{ik}\, P_{Dk} P_{Lk}$ $\ldots\ldots\ldots\ldots\ldots.(2)$
2. Water continuity equation

$$\sum_{k=1}^{T} t_k q_{jk} = V_j..(3) \quad (j = 1,2.....M)$$

......(3)

3. Minimum and maximum limit on discharge

$$q_{min} \le q \le q_{max} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(4)$$

4. Maximum and minimum limit on hydrothermal generation

$$P_i^{max} \le P \le P_i^{min} \quad \ldots..\ldots.\ldots\ldots\ldots\ldots.(5)$$

5. Maximum and minimum limit storage on reservoir
$h_{min} \le h \le h_{max} \ldots\ldots\ldots\ldots\ldots.(6)$
6. Total water discharge for 24 hrs = Vt ....(7)

3. APPLICATION OF ALGORITHM TO THE variable head hydrothermal scheduling

Parent function is generating by use random numbers is given below.

$$P_{ik} = P_i^{min} + rand_{ik}[0,1]\left(P_i^{max} - P_i^{min}\right)$$

$$i = 1,2, \ldots N + M; \quad k = 1,2, \ldots, T\ )$$

4. COMPUTER IMPLEMENTATION

Implementation of program written in Matlab Version 2013 Institute of Technology Gopeshwar, Chamoli to run on Acer Pc compatible. Have tested.

5. PROBLEM

The system test consists of hydro and thermal generation plant as
The operating cost is given by-

$$F_1(P_{1k}) = aP_{1k}^2 + bP_{1k} + C1 \qquad Rs/h$$

$$F_2(P_{2k}) = aP_{2k}^2 + bP_{2k} + C_2 \qquad Rs/h$$

The variation rates of discharge of hydro generating station are given by quadratic function of effective head and active hydro power.

$$\phi(W_{3k}) = x_1 W_{3k}^2 + y_1 W + z_1 \quad Mft^3/h$$

$$\phi(W_{4k}) = x_2 W_{4k}^2 + y_2 W_{4k} + z_2 \quad Mft^3/h$$

$$\psi(h_{1k}) = \alpha_1 h_{1k}^2 + \beta_1 h_{1k} + \gamma_1 \quad ft$$

$$\psi(h_{2k}) = \alpha_2 h_{2k}^2 + \beta_2 h_{2k} + \gamma_2 \quad ft$$

The reservoirs have small capacity and vertical sides. The coefficients of fuel cost, discharge coefficients of hydro plants, constant of proportionality, water available, surface area, initial height of the head, maximum and minimum power limits, load demand and water inflow are given in respectively. The B coefficients of the power system network are given by
B=

$$\begin{bmatrix} 0.000140 & 0.000010 & 0.000015 & 0.000015 \\ 0.000010 & 0.000060 & 0.000010 & 0.000013 \\ 0.000015 & 0.000010 & 0.000068 & 0.000065 \\ 0.000015 & 0.000013 & 0.000065 & 0.000070 \end{bmatrix}$$

MW^{-1}

Table 5.1 Thermal unit cost function coefficient

Unit	a_i (Rs/MW^2h)	b_i (Rs/MWh)	c_i (Rs/h)
1	0.0025	3.20	25.0
2	0.0008	3.40	30.0

Table 5.2Water discharge rate hydro generation function

Unit	x_i (Mft^3/MW^2h)	y_i (Mft^3/MWh)
1	0.000216	0.306
2	0.000360	0.612

Table 5.3 Water discharge rate head function

Unit	α_i (ft/h^3)	β_i (ft/h^2)
1	0.00001	-0.0030
2	0.00002	-0.0025

Table 5.4 Reservoir data

Unit	Constant of proportionality K_j	Volume of water V_j (Mft^3)	Surface area S_j (Mft^2)	Initial height h_{j0} (ft)
1	1	2850	1000	300
2	1	2450	400	250

Table 5.5 Power generation limits

Unit	Minimum Limit (MW)	Maximum Limit (MW)
1	135	281
2	316	759
3	252	439
4	11	184

Table 5.6 Load demand and water inflows

Interval (hrs)	Load demand W_D (MW)	Water inflow I1 (Mft^3/h)	Water inflow I2 (Mft^3/h)
1	800	1	0.1
2	750	2	1.3
3	700	2.75	1.75
4	700	2.9	1.95
5	700	3	2
6	750	3.25	2.25
7	800	3.4	2.4
8	1000	3.75	3
9	1330	2	2.95
10	1350	3.5	3
11	1450	4.2	3.25
12	1500	3	3
13	1300	4.3	4.3
14	1350	4.5	3.3
15	1350	4.7	3.1
16	1370	4	3.5
17	1450	4	3.7
18	1550	4.8	3
19	1430	5	4
20	1350	4.2	4.2
21	1270	6.5	4.5
22	1150	6.5	5.5
23	1000	6.5	5.5
24	900	5.4	5.5

6. OPTIMAL SOLUTION FOR TEST SYSTEM

The solution of hydrothermal generation scheduling of power systems presented here. The various parameters like population size is taken 20, variable-head hydro and thermal scheduling problem having two hydro unit and two thermal units has been solved using heuristic search method. Other different parameters maximum iterations are set to 200, the obtained value of objective function using heuristic search method algorithm is Rs 69588.9087 and obtained generation scheduled is given in Table 6.7. Result for variable head thermal and hydro generation with given load Table 6.8. Hydro and thermal acceleration coefficient ζ is 2.75.

Table 6.7 Result for Variable Head Thermal and Hydro Generation With Given Load Demand

Interval (hrs)	W_D (MW)	W_L (MW)	W_1 (MW)	W_2 (MW)	W_3 (MW)	W_4 (MW)
1	800.0	22.47132	163.40860	386.98810	260.05160	12.02233
2	750.0	19.65746	156.18010	347.52210	254.93180	11.02260
3	700.0	16.97471	136.03970	317.86830	252.00000	11.06584
4	700.0	16.97495	136.05280	317.57830	252.00020	11.34275
5	700.0	16.97157	135.40800	316.02360	253.57790	11.96125
6	750.0	19.50838	135.01970	339.64540	274.29460	20.54816
7	800.0	22.28995	145.30900	376.02120	268.45810	32.50109
8	1000.0	35.34188	175.68420	474.64360	318.14480	66.86886
9	1330.0	53.15791	234.28890	620.79690	397.02150	131.04980
10	1350.0	66.36123	260.80870	628.88100	394.29370	132.37710
11	1450.0	77.09708	274.19940	676.72330	426.15330	150.02020
12	1500.0	82.77505	275.58760	710.92650	436.08850	160.17160
13	1300.0	61.19148	228.01030	625.71790	374.68120	132.78160
14	1350.0	66.29919	225.77350	647.49660	377.79110	165.23690
15	1350.0	66.44700	260.49210	614.01740	384.76340	157.17320
16	1370.0	68.39734	258.99710	647.36740	397.60600	134.42620
17	1450.0	77.15711	266.61690	700.33310	389.99330	170.21340
18	1570.0	91.20895	280.9060	759.00000	438.99750	182.3046

			0			0
19	1430.0	74.89027	262.11180	667.05350	403.90630	171.81820
20	1350.0	66.26812	236.00910	627.32050	400.30470	152.63300
21	1270.0	58.32116	238.50250	598.31820	368.70100	122.79860
22	1150.0	47.32835	200.10430	532.94000	348.79880	115.48450
23	1000.0	35.51199	201.66370	469.31200	317.64420	46.89117
24	900.0	28.49180	175.80570	410.10490	297.68770	44.89268

Table 6.8 Hydro and thermal acceleration coefficient ζ is 2.75.

Interval (hrs)	$Y(Rs/h)$	$q_1(Mf/h)$	$q_2(Mf/h)$	$h_1(ft)$	$h_2(ft)$
1	2080.23100	84.94306	13.14447	300.00000	250.00000
2	1893.94900	82.99728	12.16616	299.91600	249.97210
3	1698.17800	81.87936	12.20703	299.83580	249.94900
4	1697.09600	81.85790	12.47607	299.75690	249.92660
5	1688.52100	82.42547	13.07883	299.67840	249.90480
6	1779.72000	90.22420	21.50776	299.59800	249.88080
7	1964.36100	87.97879	33.37463	299.51200	249.83450
8	2488.36900	107.26730	68.38697	299.42830	249.76240
9	3360.97400	139.84610	137.27010	299.32570	249.60140
10	3514.22900	138.61530	138.52630	299.18990	249.27020
11	3787.62500	152.36590	158.03580	299.05630	248.93440
12	3948.23500	156.67760	169.24230	298.91040	248.55560
13	3355.26400	130.11870	138.23400	298.76030	248.14600
14	3441.79900	131.36800	174.39470	298.63020	247.80360
15	3447.48800	134.25060	164.90570	298.50060	247.37250
16	3587.80600	139.65220	139.26860	298.36840	246.96590
17	3859.39100	136.34570	179.07230	298.23110	246.62520
18	4192.63400	157.54370	192.51660	298.09770	246.18500
19	3689.46500	142.15400	180.11710	297.94350	245.71120
20	3397.19500	140.54550	158.20740	297.80560	245.26920

21	3281.08600	127.15690	125.30370	297.66820	244.88240
22	2834.65400	118.91500	117.28840	297.54470	244.57670
23	2573.85900	106.36080	46.63707	297.42980	244.29390
24	2223.75300	98.51138	44.63926	297.32790	244.19110
The period time is scheduled for 24h			V_1 = 2850.0008 Mft3		
Total operating cost=Rs 69785.88			V_2 = 2450.0007 Mft^3		

Table 6.9 Total system operating cost w.r.t mutation factor

POPULATION	TOTAL SYSTEM OPERATING COST (Rs)		
	F is 0.8	F is 0.85	F is 0.90
10	69824.04	69885.60	69871.73
20	69808.22	69841.59	69815.34
30	69801.53	69800.95	69795.78
40	69792.07	69799.72	69797.91
50	69802.09	69829.59	69787.35
60	69793.34	69804.51	69805.88
70	69797.02	69796.89	69796.13
80	69785.88	69798.11	69803.26

XI=39 ZETA=0.26 ITERATIONS=100

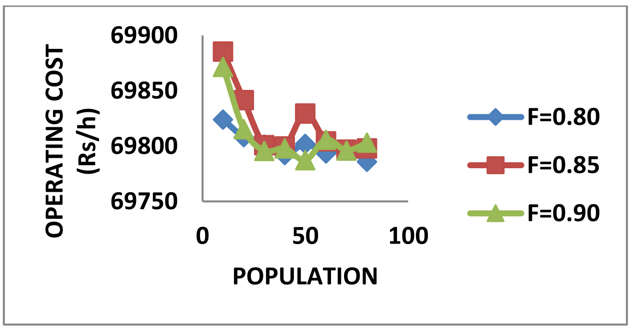

Fig. 6.1 Operating cost over the population at different mutation factors

Table 6.10 Total system operating cost w.r.t maximum iteration

POPULA-TION	TOTAL SYSTEM OPERATING COST (Rs)		
	Generation (Iterations) is 100	Generation (Iterations) is 150	Generation (Iterations) is 200
10	69824.04	69824.04	69824.04
20	69808.22	69808.22	69808.22
30	69801.53	69801.53	69801.53
40	69792.07	69792.07	69792.07
50	69802.09	69802.05	69802.04
60	69793.34	69793.34	69793.33
70	69797.02	69796.84	69796.84
80	69785.88	69785.42	69785.42

XI=39 ZETA=0.26 F=0.8

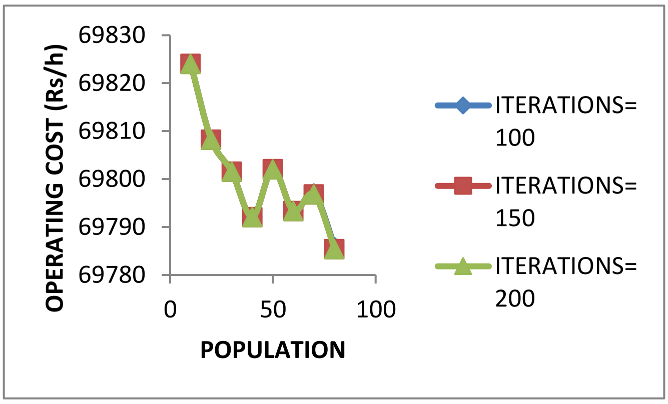

Fig. 6.2 Operating cost over the population at different maximum iterations

Table 6.11 Comparisons of results

Method	Operating cost (Rs)
Newton-Raphson	69801.08/-
Heuristic search method	69785.88/-

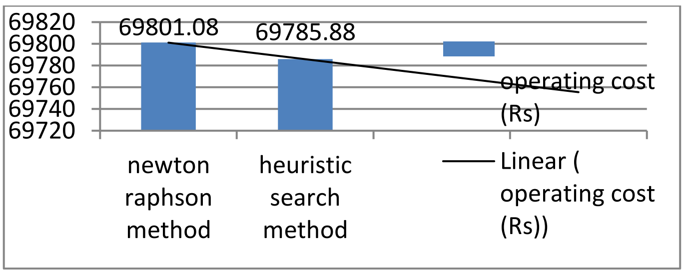

Fig 6.3 Comparison Chart

The total cost obtained from the heuristic search method is less as that of newton-rapson method [6].

Thus it can be concluded that heuristic search method technique provides optimum results the newton-rapson method. It is better to use heuristic search method because newton-rapson method cannot be applied to the hydrothermal scheduling problem having prohibited zone constraints.. While implementing heuristic search method there is no need of initial guess of power and water discharge. Hence it is better to use heuristic search method.

7. Conclusion

The heuristic method is based and used to solve the variable-head hydrothermal scheduling problem. A hydrothermal model has been implemented to find the optimum power generation schedule considering the transmission power losses. The heuristic search technique is having dynamic characteristics function utilized to update the solution vector and improves the convergence properties of the algorithm.

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